Today, we will:

- Review the pdf module: **Volume and Mass Flow Rate Measurement** (last one!) ☺
- Do some example problems – pressure, velocity, and volume flow rate measurement
- Discuss some additional items about pressure and velocity measurement not in the notes

Example: Pressure measurement

Given: Jeri decides to use a soda can as a simple pressure cell. She mounts a strain gage on an empty soda can, much like was done in the strain gage lab. The soda can diameter is 66.0 mm and the wall thickness of the cylindrical portion is 0.105 mm. The aluminum has a Young's modulus of 70. GPa and a Poisson ratio of 0.35. The strain gage has a no-load resistance of 120.1 Ω and a strain gage factor of 2.10. Jeri constructs a quarter bridge circuit using resistor R_3 as the strain gage. She sets the bridge supply voltage to 5.00 V. She balances the bridge with zero gage pressure by setting the other three resistors in the Wheatstone bridge to 120.1 Ω. The opening to the can is then connected to a pressure line subjected to the pressure Jeri wishes to measure.

To do: When the measured output voltage from the Wheatstone bridge is 3.89 mV, calculate the applied gage pressure in units of kPa. Also calculate the hoop strain in units of microstrain.
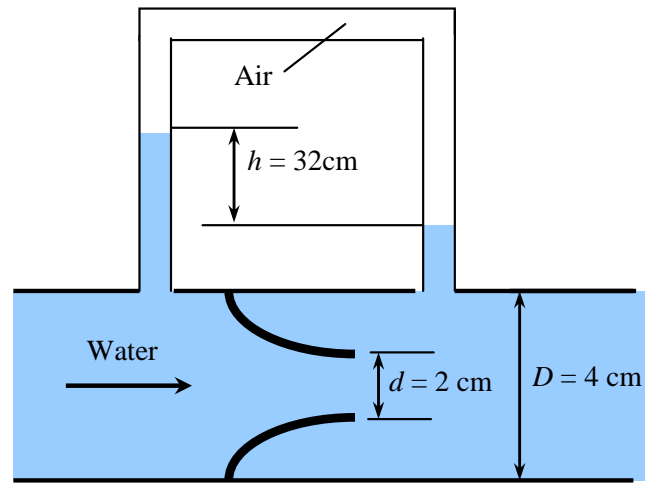
Solution:

Example: Volume flow rate measurement

Given: Water at 20°C (ρ_w = 998 kg/m³ and μ_w = 1.002 × 10⁻³ kg/m·s) flows through a 4.0-cm pipe equipped with a flow nozzle and an *inverted* air-water manometer. ρ_{air} = 1.204 kg/m³.
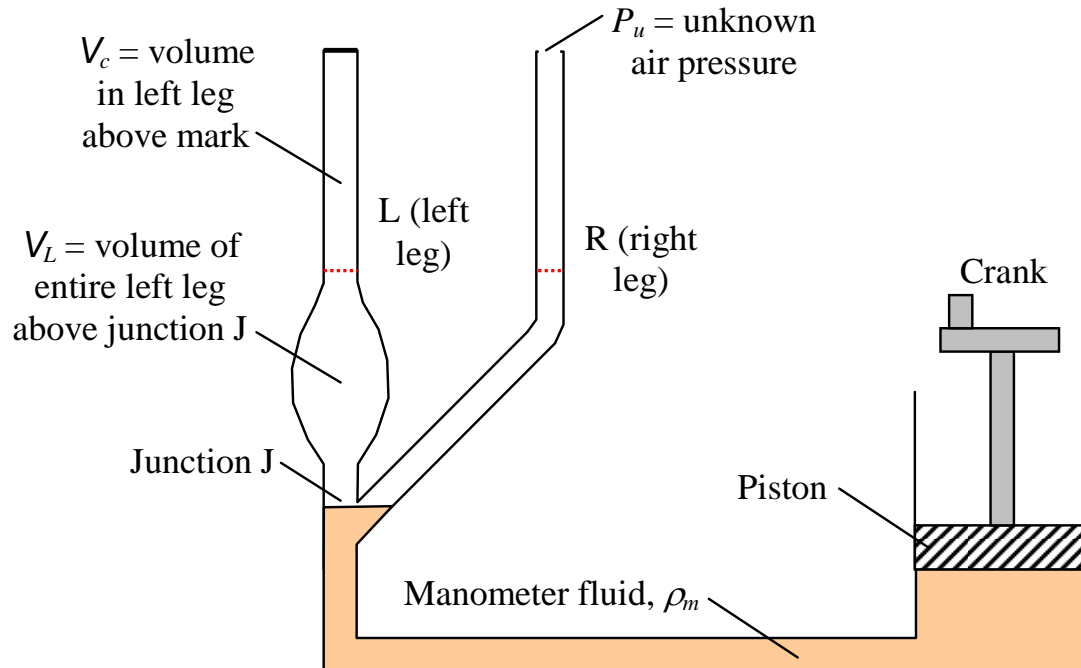
To do: Calculate the volume flow rate.

Solution:

Additional Notes: The McLeod Gage
A **McLeod gage** is a special type of U-tube manometer to measure very low pressure:

P_u = unknown
air pressure

V_c = volume
in left leg
above mark

L (left
leg)

R (right
leg)

Crank

V_L = volume of
entire left leg
above junction J

Piston

Junction J

Manometer fluid, ρ_m

Procedure (do all this at constant temperature – *isothermally*):
1. Start with $P_L = P_R = P_u$ as sketched (the manometer fluid is just below junction J).

2. Crank down the piston until the manometer fluid seals off the air at junction J in the left leg.

3. Keep cranking until the manometer fluid reaches the red mark on the left leg – the manometer fluid in the right leg will rise higher, because the air in the left leg is *compressed* (higher air pressure).

4. Measure column height h.

5. Calculate the unknown pressure, P_u.

V_c, P_c

P_u

h
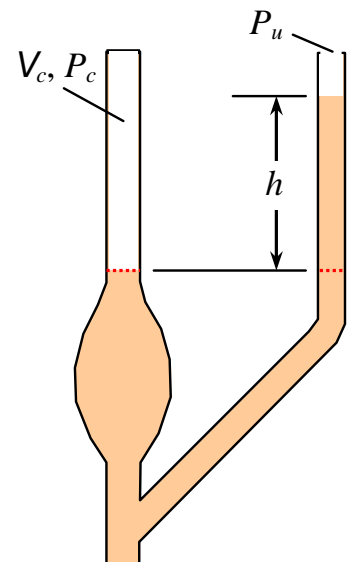
Dynamic calibration of a pressure transducer

Shock tube: [Designed to send a shock wave (sudden increase in pressure) down a tube]